LESSONS LEARNED FOR GEOLOGIC DATA COLLECTION AND SAMPLING: INSIGHTS FROM THE DESERT RATS 2010 GEOLOGIST CREWMEMBERS. J. M. Hurtado, Jr.[1], J.E. Bleacher[2], J. Rice[2], K. Young[3], W.B. Garry[4], D. Eppler[5]. [1]University of Texas at El Paso, Department of Geological Sciences & Center for Space Exploration Technology Research, El Paso, TX, 79968, jhurtado@utep.edu, [2]Planetary Geodynamics Laboratory, Code 698, NASA Goddard Space Flight Center, Greenbelt, MD, 20771, [3]Arizona State University, School of Earth & Space Exploration, Tempe, AZ, 85282, [4]Center for Earth and Planetary Studies, Smithsonian Institution, PO Box 37012, National Air and Space Museum MRC 315, Washington, D.C. 20013, [5]NASA Johnson Space Center, Astromaterials Research & Exploration Sciences Directorate, Houston, TX, 77058.

Introduction: Since 1997, Desert Research and Technology Studies (D-RATS) has conducted hardware and operations tests in the Arizona desert that advance human and robotic planetary exploration capabilities. D-RATS 2010 (8/31-9/13) simulated geologic traverses through a terrain of cinder cones, lava flows, and underlying sedimentary units using a pair of crewed rovers and extravehicular activities (EVAs) for geologic fieldwork. [1]. There were two sets of crews, each consisting of an engineer/commander and an experienced field geologist drawn from the academic community. A major objective of D-RATS was to examine the functions of a science support team, the roles of geologist crewmembers, and protocols, tools, and technologies needed for effective data collection and sample documentation [2]. Solutions to these problems must consider how terrestrial field geology must be adapted to geologic fieldwork during EVAs [3, 4].

Geologic Field Work: Observation is the primary function of planetary field geologists, and their verbal observations, supported by imagery, will be the most important data stream relayed to Earth. It is through these observations that the geology of a field site will be documented, investigated, and interpreted. Field observations also support sample collection, a necessary, but secondary, task. While samples are vital for laboratory analyses, the quality of those samples and the resulting datasets is highly dependent on the field observations. Careful consideration must be made of issues that impact the interplay between field observations and sample collection. These include the time/task management; the degree of duplication in samples/observations; and logistical constraints on the volume/mass of samples and data that can be collected, stored, and ultimately returned to Earth.

D-RATS 2010 Geologic Field Protocols: Before EVAs, the crew is tasked with obtaining imagery and observations of the site from inside the rover (see [4] for more details). This is supplemented by a verbal overview of the EVA plan once the crew has egressed. These are critical opportunities for the crew to detail their field plan and establish context for their work, including samples to be collected and their locations. During the EVA, each sample is systematically collected using a variety of tools (e.g., rock hammer, shovel, tongs, core-tube, sample bags), although the crew did lack a hand lens, one of the most basic tools used by a field geologist. A pair of cameras on the crewmembers' simulated suits – a "webcam" for real-time imagery and a high-definition (HD) camera for archival imagery – and a cuff-computer-controlled voice annotation system is used to document the samples and to record geologic observations with voice-tagged imagery ("crew field notes", CFNs; see [5]). The sampling procedure is: 1) Place tool on outcrop for scale; 2) Take context still HD image from 10 ft.; 3) Take stereo HD video from 5 ft.; 4) Collect sample and give detailed description over the voice loop with the sample in the field of view of the webcam; 5) Start CFN and (re)describe sample and context with the sample and sample bag in the field of view of the HD camera; 6) Take still HD image of sample and bag; 7) Stow sample in bag and retrieve tools. At the end of the EVA, a complete inventory of all the samples collected is taken as a CFN before stowing them, and a verbal overview of geologic observations is recorded once the crew has ingressed. The entire process of doing field geology during EVAs is heavily technology dependent, including communications and telemetry. See [4] for more details about EVAs.

Time and Task Management: The crew has the responsibility to achieve the science objectives while operating within the framework of the timeline and the field protocols. The question becomes: how is science productivity defined and assessed? Several metrics are possible, including the degree to which the daily objectives are met, the incremental increase in science understanding, or a more quantitative measure, such as the number of samples collected. Our experience shows that the number of samples collected is very site and mission dependent, and overemphasis on sampling vs. fundamental observation can lead to artificial pressures resulting in poorly-chosen samples and inadequate documentation. Most importantly, it ignores the overriding importance of context and the value of a single "perfect" sample vs. several "imperfect" ones. Time spent making the important geologic observations and characterizing context is well worth it if it results in a properly documented sample that meets the requirements of the science team, even if fewer samples are collected. Time management is critical because it takes ~10 min. to collect each sample, a large commitment, given that most EVAs were ~30-60 min.

long. A significant amount of this is time committed before even picking up the rock (i.e. taking context imagery, etc.), and perhaps realizing that one should have sampled somewhere else or not at all. The crew must weigh the time to collect multiple samples vs. the time to best characterize and pick fewer samples.

Duplication of Effort: With multiple rovers in the field, duplication of effort may occur and could be used as a measure of crew effectiveness, as excessive duplication of samples/observations may suggest poor planning and/or crew coordination. Alternatively, some degree of duplication may be tolerable or beneficial. For example, by using assets such as the PEM/GeoLab for *in-situ* analyses [6] and/or robotic follow-up [7], "excess" samples not returned to Earth can still be of scientific value. In fact, multiple specimens of the same geologic material may be required by some science objectives to determine lateral/vertical variability at a number of scales Similarly, some analytical methods benefit from multiple samples. Finally, sample duplication may retire the scientific risk of losing critical material in the event of a mission failure. With respect to duplication of observational data, field geology has always enjoyed the benefit of multiple perspectives on problems. Having observational data from more than one person can provide important insights [8]. For example, the 2010 crews found that it was valuable to compare observations after EVAs to understand if they collected/observed the same unit on different sides of a feature such as a fault or gully [8].

Storage Considerations: While none of the crew geologists collected an inordinate number/volume of samples, physical storage constraints will affect the individual sizes of samples collected and the total number of samples collected per EVA/mission. For EVAs, the crew suggests larger sample bags that allow for larger specimens required to illustrate particular, scale-dependent structures or textural features or to provide enough material for particular kinds of analyses. In addition, stowage and carriage of tools and samples on EVA was problematic. Because the supplied caddy was not often used [4], the crew was limited in the amount of material they could carry by hand in bags or in bags clipped to their belts. Another limitation is on-rover stowage. The crews found that the volume/number of sample stowage containers and the sample locker were marginally large enough. Future tests may include increased space and involve sample caches utilizing deployable assets already in use. The volume/bandwidth constraints for storage/transmission of voice/image data seemed sufficient for the crew.

Geology Crew Recommendations:

Traverse Planning and Training: To avoid duplication of effort, adequate inter/intra-crew communication is needed, particularly while on EVA. EVAs can be designed such that potential duplication is explicitly pointed out (also point out where duplication is required). Above all, since the crew has *de-facto* final authority for science activates, they must always be cognizant of the science objectives through science team briefings/debriefings and participation in the mission planning process. One possibility is to have a field science PI, a geologist crewmember with oversight authority over the field geologic activities.

Field Geology Protocols: The protocol (and EVA timeline) should be adjusted to include time to ensure that outcrops are thoroughly evaluated prior to committing to a sample. The sample documentary process would only begin after a good sample has been identified, even potentially extracted. This will require the necessity for imagery of pristine, *in-situ* samples prior to sampling to be relaxed. The benefit would be improved geologic context and better-chosen samples. In addition, continued refinement of a systematic checklist for geologic observations is needed.

Tools and Technologies (see also [4]): Since technology affects much of the geologic observation and sample collection process, improvements to the cameras and data recording systems are warranted. For example, better on-suit camera positioning/targeting and the use of a single camera system for both realtime and recorded imagery is needed, as well as the ability to annotate imagery. The inclusion of a hand lens or similar capability will be very useful in order to conduct observations at the micro-scale, which can help to better characterize samples and improve descriptions. Continued refinement of the CFN system, the field tools, and sample stowage is also needed.

Mission Evaluation: The value of geologic observations must be recognized as equal and complementary to the value of tangible geologic specimens. There must be recognition that time spent observing and not sampling is not time wasted. There must not be bias toward using the number of samples (and/or the degree of geologic duplication) as metrics for crew performance and science return. Field protocols and mission plans should be designed to properly enable real-time decision making to support the effective balance between geologic observations and tactical sampling.

References: [1] Horz et al. (2011), this volume. [2] Eppler et al. (2011), this volume. [3] Hodges et al. (2010), A New Approach to Planetary Field Geology, *GSA Abs. w/ Prog.*, v. 42 (5), p. 64. [4] Young et al. (2011), this volume. [5] Horz et al. (2011), this volume. [6] Evans et al. (2011), this volume. [7] Fong et al. (2010) Robotic Follow-up for Human Exploration, *AIAA*. [8] Bleacher et al. (2011), this volume.